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Herbicide Resistance, Weed Population Shifts, and Weed Management Stewardship: Is Anything New?

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Introduction

As glyphosate-resistant soybean and corn production systems are becoming the standard for Iowa and the Midwest, the selection pressure imposed on the agro-ecosystem by glyphosate is likely increasing at an increasing rate. World-wide, 11 weed species have been reported as having evolved glyphosate-resistant biotypes (Heap 2006). Nine of the glyphosate-resistant biotypes were reported after 2000, and four glyphosate-resistant biotypes were reported in 2005. It is clear that the evolution of glyphosate-resistant weeds is increasing at an increasing rate.

While ISU reported the existence of glyphosate-resistant common waterhemp in 1998, the relative economic importance of glyphosate-resistant weed biotypes in Iowa has to date, not been of major consequence. However, the lack of significant glyphosate resistance in Iowa weed communities can be anticipated to change based on reports and observations of glyphosate-resistant weed biotypes in neighboring states and anecdotal comments from the agricultural community. Furthermore, the occurrence of Asiatic dayflower and other weed population shifts attributable to selection pressure from glyphosate use is more frequent. Thus, the need to consider the implications of not stewarding glyphosate use is more important than ever.

Grower attitudes

Iowa State University weed scientists have provided information about the potential evolution of herbicide resistant weed biotypes and weed population shifts for the last 15 years or longer. The evolution of ALS-resistant weeds, glyphosate-resistant weeds, and various changes in weed communities (e.g. woolly cupgrass) have been predicted with relative accuracy by ISU extension weed specialists. Furthermore, ISU extension has made an incredible effort in alerting growers of these impending problems and how to reduce the likelihood of these changes in the weed community occurring.

To date, it is questionable if these efforts alerting growers about the impending weed problems have been accepted by Iowa agriculture, and it appears, given the problems that ultimately evolved, that these efforts were largely a waste of time. Growers perhaps understood the implications of evolved herbicide resistance, but did not appreciate the economic implications based on the anticipated availability of glyphosate-resistant crop technology and the mistaken impression that weeds would not/could not evolve resistance to glyphosate.

Perhaps the attitude of Iowa growers is similar to the attitude exhibited by Indiana growers. In a recent survey, 66% of the responding growers expressed only a moderate or low level of concern about weeds developing resistance to glyphosate (Johnson and Gibson 2006). This is very surprising given the problems that exist with glyphosate-resistant horseweed and suspected glyphosate-resistant giant ragweed and common lambsquarters. It was interesting that growers who farm larger acreages are more likely to be concerned about the potential for evolved glyphosate- resistant weeds and willing to adopt resistant management strategies. One telling fact was that while a majority of the respondents understood the role of repeated use of a herbicide for the selection for herbicide resistant weeds, only 38% of the respondents, irrespective of farm size, did not understand the implications of using a herbicide(s) with the same mode of action repeatedly. Furthermore, Indiana growers, similar to Iowa growers, appear to be adopting glyphosate-resistant corn at an increasing rate. This practice will likely increase the selection pressure for glyphosate-resistant weeds unless appropriate management strategies are adopted.

Selection pressure increases at an increasing rate

Weed management practices that are highly effective but narrow in the scope of tactics included exert the greatest selection pressure on the weed community. The result of intense selection pressure is either the evolution of herbicide-resistant weed biotypes or shifts in the relative prominence of one weed species in the overall weed community (Hilgenfeld et al. 2004). These changes are inevitable unless due consideration is given to developing a diverse weed management program and reducing the selection pressure imparted by the weed management practices used.

The adoption of glyphosate-based crop production systems has been one of, if not the most important revolution in the history of agriculture. Currently, approximately 95% of the soybeans grown in Iowa are glyphosate-resistant. It is projected that 50% of the Iowa corn acres will be glyphosate-resistant hybrids and projections are that 53% of the US corn acres will glyphosate-resistant hybrids. Unless growers proactively initiate weed management programs that will dilute the selection pressure imposed by the repeated use of glyphosate, weeds that are poorly controlled by glyphosate, regardless of the physiological or biochemical basis, will become a major economic problem in Iowa.

While the only glyphosate-resistant weed species reported in Iowa is common waterhemp (Zelaya and Owen 2000), anecdotal evidence suggest that common lambsquarters, giant ragweed, annual morningglory, Asiatic dayflower, and horseweed infestations are increasing in glyphosate-resistant crops grown in Iowa. It is clear that grower use of glyphosate is imposing incredible selection pressure on the weed communities and that change in the weed communities to species that do not respond to glyphosate are increasing at an increasing rate.

The gravity of the impending situation is well-understood by the industry and many companies are advocating diverse weed management tactics and glyphosate stewardship programs. For example, Monsanto recommends the use of soil-applied herbicides in glyphosate-resistant corn and soybean (Anonymous 2005). However, it does not appear that growers understand the implications of the selection pressure they are imposing on the agroecosystem and thus far, are not implementing appropriate tactics to delay the changes in the weed communities brought forth by the glyphosate-based weed management programs. It is likely that many growers see glyphosate stewardship as an additional production expense and do not appreciate the positive economic implications of proactive glyphosate-resistant weed management (Mueller et al. 2005). It is also likely that growers anticipate that the agricultural chemical industry will once again come to the rescue with a new herbicide to resolve the new glyphosate-resistant weed problems or weed population shifts. While the agricultural chemical industry has historically been remarkably successful with developing herbicide solutions to new problems, it is not likely that new chemistry can be developed to easily and cheaply resolve the weed problems that have been documented, or are anticipated in glyphosate-based crop production systems.

Glyphosate resistant weeds

The list of weeds that have been reported as glyphosate-resistant on the International Survey of Herbicide Resistant Weeds (www.weedscience.org) now includes 11 species. The first glyphosate-resistant weed reported was Rigid Ryegrass from Victoria, Australia in 1996. The list now includes six weeds that have evolved resistance to glyphosate in 15 states in the United States. Two new weed species, common waterhemp (*Amaranthus rudis*) and Palmer amaranth (*A. palmeri*), were added to the list in 2005. What is misleading about the list of herbicide-resistant weeds included on the International Survey of Herbicide Resistant Weeds is that weed scientists must document the resistance and then report the information to the survey. It is likely that many weed populations have demonstrated herbicide resistance but are not included on the site. Thus, the information included on the website should be considered as an incomplete picture of herbicide-resistant weed populations world-wide.

Common waterhemp

While the reported occurrence of glyphosate-resistant common waterhemp populations has not changed dramatically since the 2005 report, growers are anecdotally reporting escalating issues with common waterhemp management with glyphosate. ISU reported that rare individual common waterhemp plants within populations demonstrated heritable resistance to glyphosate in 1998, and while it is likely that the glyphosate-resistant biotype has increased in numbers, the populations have yet to approach the level (anecdotally suggested to be 30% of a population) that growers notice. Thus, only two Missouri fields where soybeans have been grown continuously for over 25 years, and glyphosate has been the only herbicide used since the introduction of glyphosate-resistant soybeans have levels of glyphosate-resistant common waterhemp that are problematic. It is important to note that these glyphosate-resistant common waterhemp populations are also resistant to ALS inhibiting herbicides (Heap 2006). Common waterhemp populations that demonstrate multiple resistance to four modes of action (Patzoldt et al. 2002)

Our data demonstrated clearly that the genetically heritable trait for glyphosate resistance exists within common waterhemp populations but at a very low frequency. Furthermore, it appears that the trait for glyphosate-resistance is polygenic. However, given the selection pressure from the consistent use of glyphosate on glyphosate-resistant soybean and corn, the frequency of glyphosate-resistant common waterhemp will continue to increase at an increasing rate in Iowa unless a diversity of weed management tactics are employed.

Palmer amaranth

Glyphosate-resistant Palmer amaranth has been confirmed in Georgia (Culpepper et al. 2006). While Palmer amaranth is not a common weed in Iowa, the significance of the information is that evolved resistance to glyphosate is being discovered frequently and over a broad geographic and crop production range. Palmer amaranth is described as the most aggressive and competitive of the pigweed species. Palmer amaranth populations are increasing in Illinois, Missouri and Kansas. Palmer amaranth populations have also been reported to demonstrate resistance to ALS, triazines, DNA and PPO inhibiting herbicides.

Common ragweed

Populations of glyphosate-resistant have now been reported in Missouri and Arkansas. However, again the glyphosate-resistant common ragweed populations appear to be isolated to specific fields and have not spread appreciably to date. It is unlikely, based on the cursory information available, that glyphosate-resistant common ragweed will become a serious agronomic problem in Iowa. However, it is interesting to note that common ragweed has evolved resistance to six different herbicide mechanisms of action.

Horseweed

Evolved glyphosate resistance to horseweed (also commonly known as marestail) has continued to spread widely and rapidly across the eastern Corn Belt. Most recently, glyphosate-resistant horseweed was reported in Nebraska (Knezevic and Martin 2006). There are reports of glyhphosate-resistant horseweed in Illinois and Missouri. Growers in southwest Iowa have also reported difficulties controlling horseweed. Thus, it is probable that populations of glyphosate-resistant horseweed exist in Iowa. Our data demonstrate that the genetic trait for glyphosate resistance is controlled by a single semi-dominate gene. Given the incredibly high seed production, the fact that the seeds are wind-dispersed, and the adaptation of horseweed to conservation tillage programs, it is obvious why glyphosate-resistant horseweed is a major concern for agriculture.

Giant ragweed

The data to confirm the existence of glyphosate-resistant giant ragweed populations in Ohio and Indiana continues to mount. Given this information, and the fact that giant ragweed populations continue to increase in the eastern half of Iowa, growers should consider it highly likely that glyphosate-resistant populations will eventually evolve in Iowa. Importantly, many/most of the giant ragweed populations in Iowa have already evolved resistance to ALS inhibiting herbicides. Be aware that giant ragweed is difficult to manage consistently regardless of whether or not glyphosate-resistant populations evolve.

Common lambsquarters

The importance of common lambsquarters as an economic problem in Iowa has increased considerably during the last 10 years. Recent reports confirm that there are glyphosate-resistant populations in Ohio, Indiana, Delaware, and Virginia (Westhoven et al. 2006, Loux and Strachler 2005, and Curran 2005). Suspect populations of common lambsquarters that are difficult to control consistently with glyphosate have been identified in Wisconsin and North Dakota (Boerboom 2005, Zollinger 2006) Iowa growers have also indicated problems controlling common lambsquarters with glyphosate. Common lambsquarters is difficult to control with glyphosate regardless of the existence of resistance. While populations of common lambsquarters have been identified as glyphosate-resistant, most of the control problems in Iowa are likely attributable to factors other than resistance. Using too low rates, spraying too large plants, or when conditions are not favorable for control account for most of the problems with common lambsquarters in Iowa. However, the existence of glyphosate-resistant common lambsquarters populations in Iowa cannot be discounted. Thus, multiple tactics should be employed for the most consistent management of common lambsquarters infestations.

Weed population shifts

Weed population shifts are typically a long-term response to multiple selection pressures imparted on the agroecosystem. These selective factors are usually more complex than illustrated in the evolution of herbicide-resistant biotypes, and the speed at which weed population shifts occur is generally slower than the change that occurs when herbicide-resistant populations evolve. However, adoption of weed management programs that focus on one herbicide mode of action have hastened several important weed population shifts in Iowa. The use of ALS inhibitor herbicides, in part, resulted in the relatively rapid rise in prominence of common waterhemp. Glyphosate-based systems have resulted in increasing problems with common lambsquarters, winter annuals, common waterhemp, and morningglory species (Culpepper 2006).

A recent, albeit relatively isolated, weed population shift that has surfaced in response to the adoption of glyphosate technology is occurrence of Asiatic dayflower. However Asiatic dayflower infestations are increasing based on grower reports in Iowa, Wisconsin and Illinois. Asiatic dayflower is naturally tolerant to glyphosate, and cannot be controlled almost irrespective of the glyphosate application rate. Field research conducted by ISU weed scientists has not been successful in identifying a consistent control solution for this weed in soybean. Corn systems utilizing atrazine, 2,4-D, or Callisto may prove to be the best option. However, recognize that glyphosate-based weed management will only increase the infestations of Asiatic dayflower and at an increasing rate. It is clear that increased diversity of weed management tactics must be implemented to keep this weed as a rare and scattered problem.

Conclusions

Evolved glyphosate resistance in several weed species has become more common and is becoming more problematic at an increasing rate. Glyphosate-resistant weeds can be found in Iowa, although specific problems other than common waterhemp have not been specifically identified. However, anecdotal reports from growers suggest that glyphosate-resistant weeds exist in Iowa. Given the wide spread adoption of glyphosate-resistant soybean and corn, glyphosate will continue to be applied consistently on fields every year. The level of selection pressure imparted on a field by this management strategy will inevitably result in weeds that are not managed effectively by glyphosate.

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